

A Survey of TBT Capabilities of the Upgraded TeV BPMs

Rob Kutschke, CD/EXP

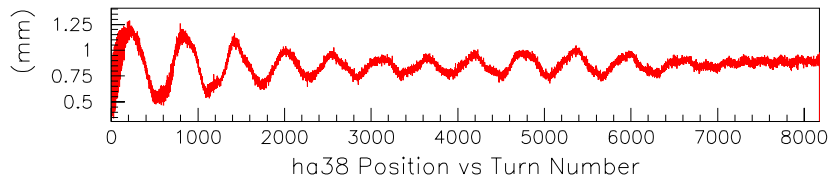
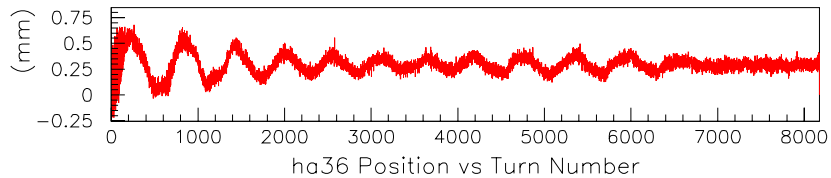
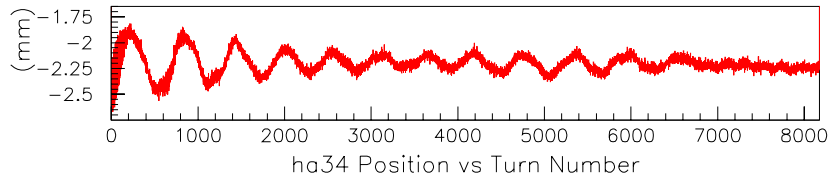
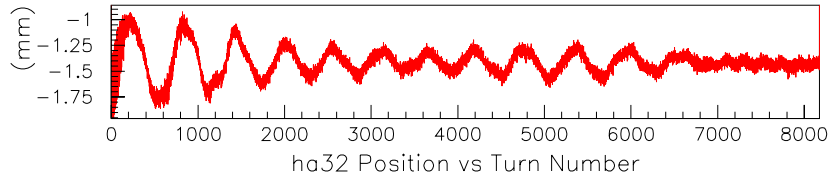
Tevatron Department Meeting

February 18, 2005

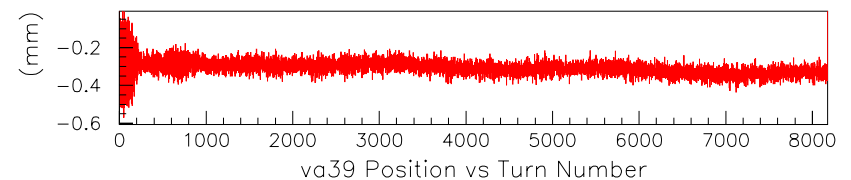
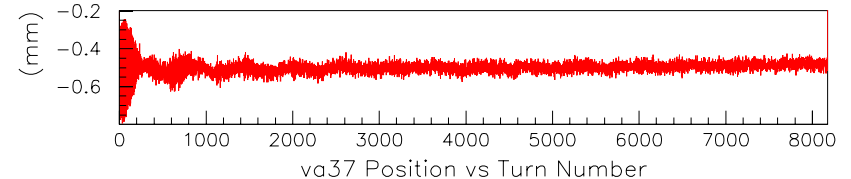
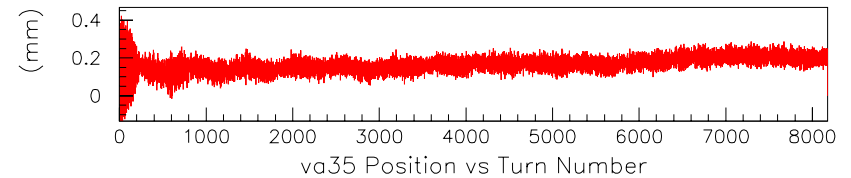
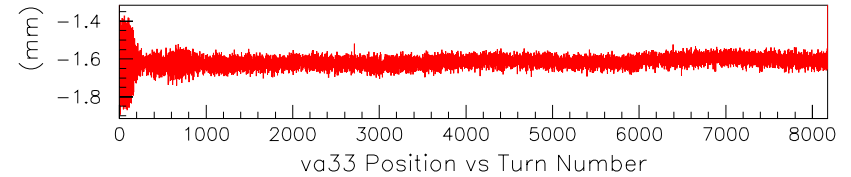
This Talk Will Show:

- Injection TBT
 - Triggered by injection.
 - Either single bunch or uncoalesced beam.
 - Can see: synchrotron motion, betatron motion, quadrupole oscillations of bunch in the bucket, HV coupling, plus some instrumental artifacts.
- TBT
 - Triggered by request.
 - Will show 36x36 during normal HEP store.
 - Do NOT ping beam.
 - Can see the “15 Hz” motion.
- Using data taken at A3 over the past two weeks.

Position for H BPMs in A3, Feb 6/05, Coalesced



Position for V BPMs in A3, Feb 6/05, Coalesced

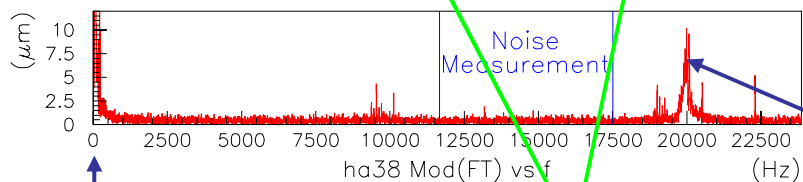
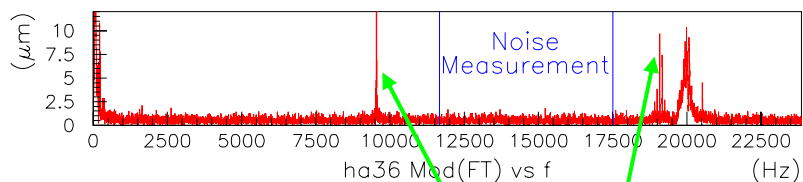
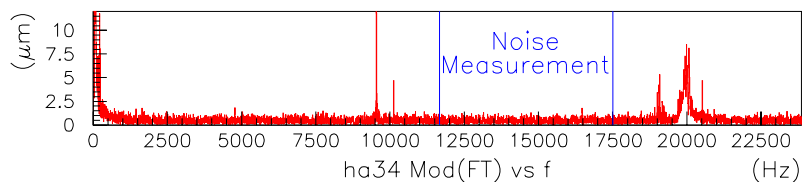
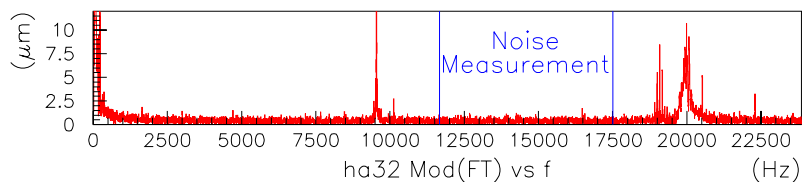


1.1 mm full vertical scale

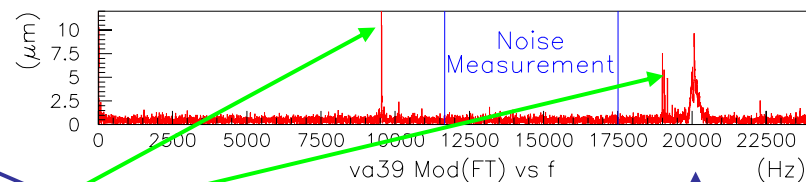
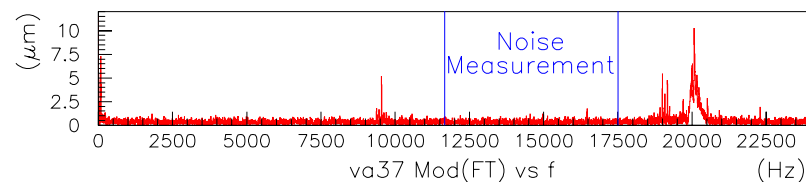
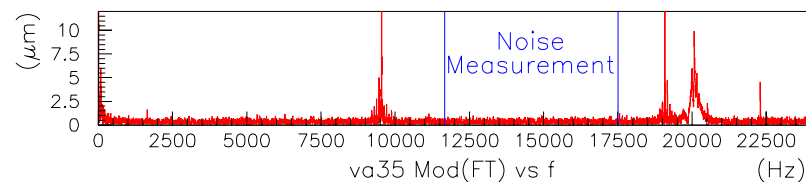
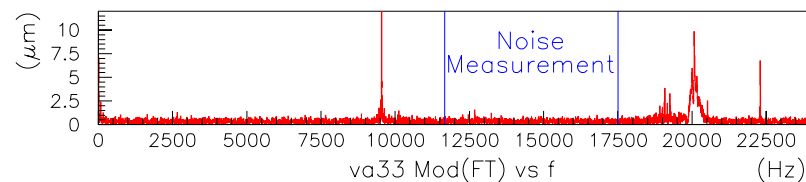
0.6 mm full vertical scale

- Injection TBT; 150 GeV; 8192 turns.
- One coalesced bunch. HEP shot after all tuning.

Detail of Mod(FT) for H BPMs in A3, Feb 6/05, Coalesced



Detail of Mod(FT) for V BPMs in A3, Feb 6/05, Coalesced



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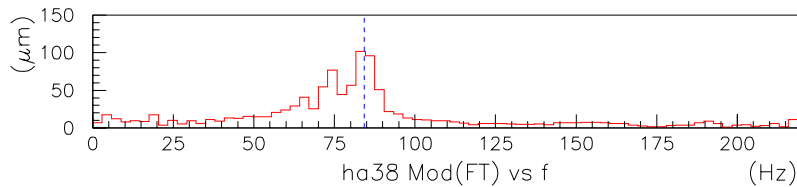
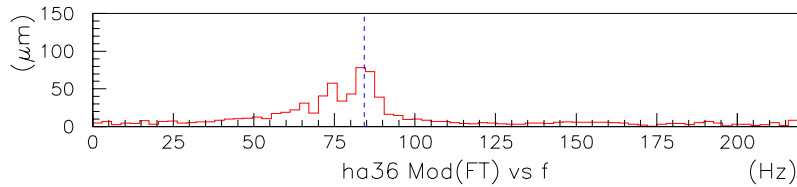
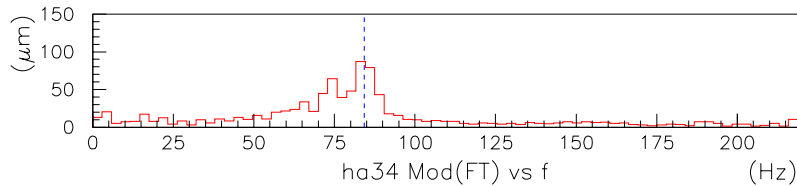
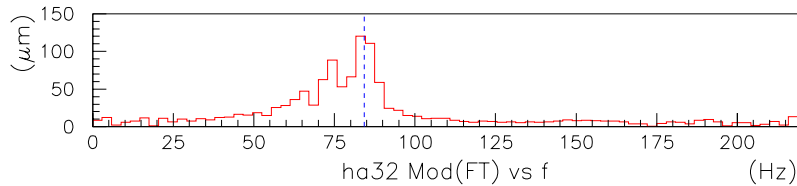
Bin Size: ~3 Hz

Resolution: $0.3 \mu\text{m}/\sqrt{\text{Hz}}$

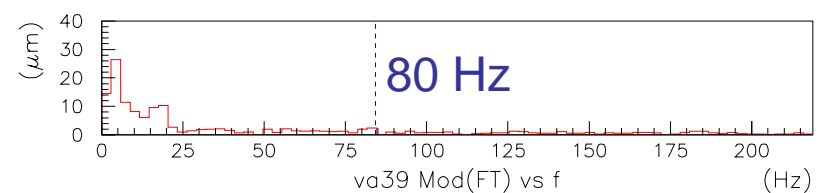
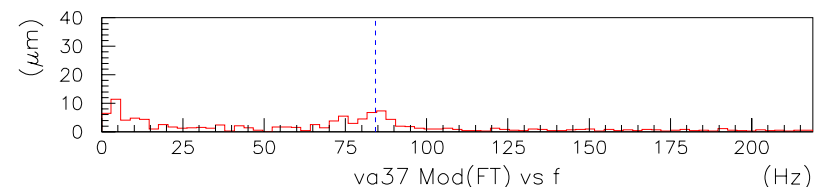
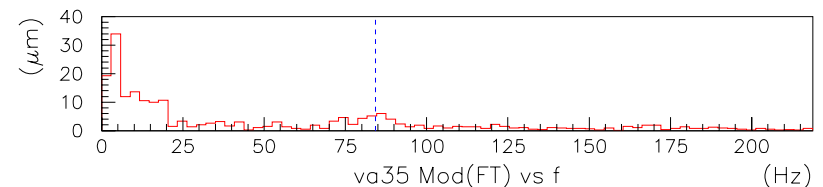
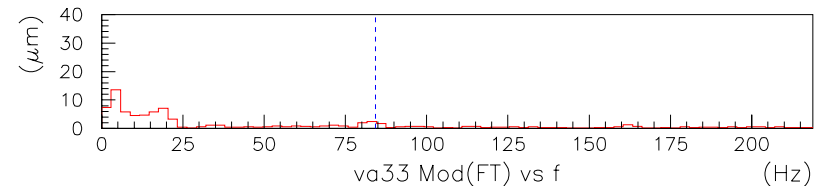
Synchrotron Line

Betatron Lines

Detail of Mod(FT) for H BPMs in A3, Feb 6/05, Coalesced

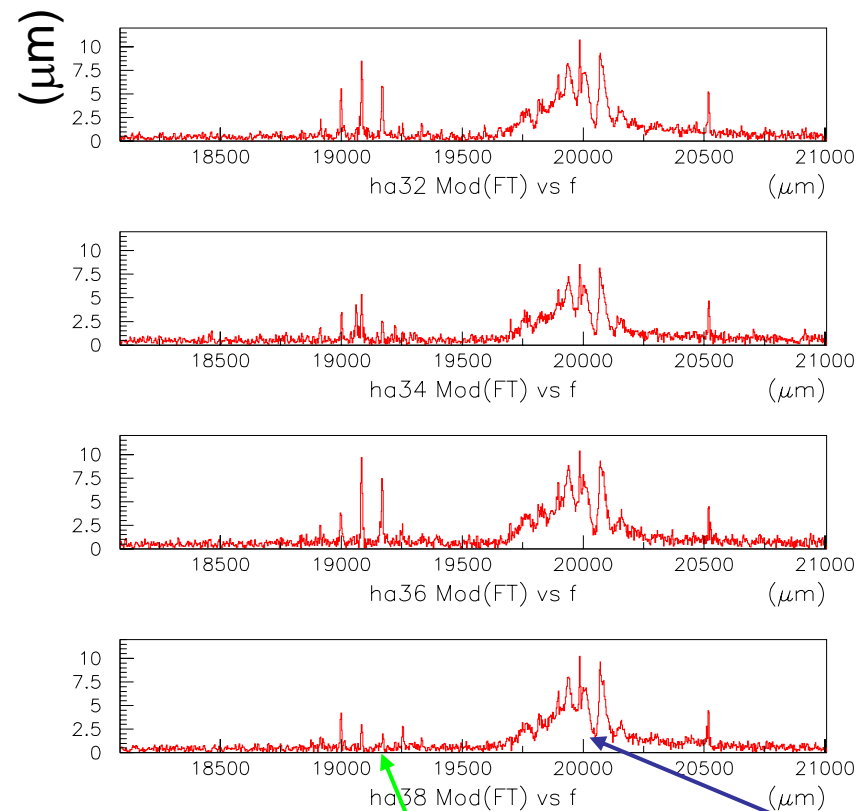


Detail of Mod(FT) for V BPMs in A3, Feb 6/05, Coalesced

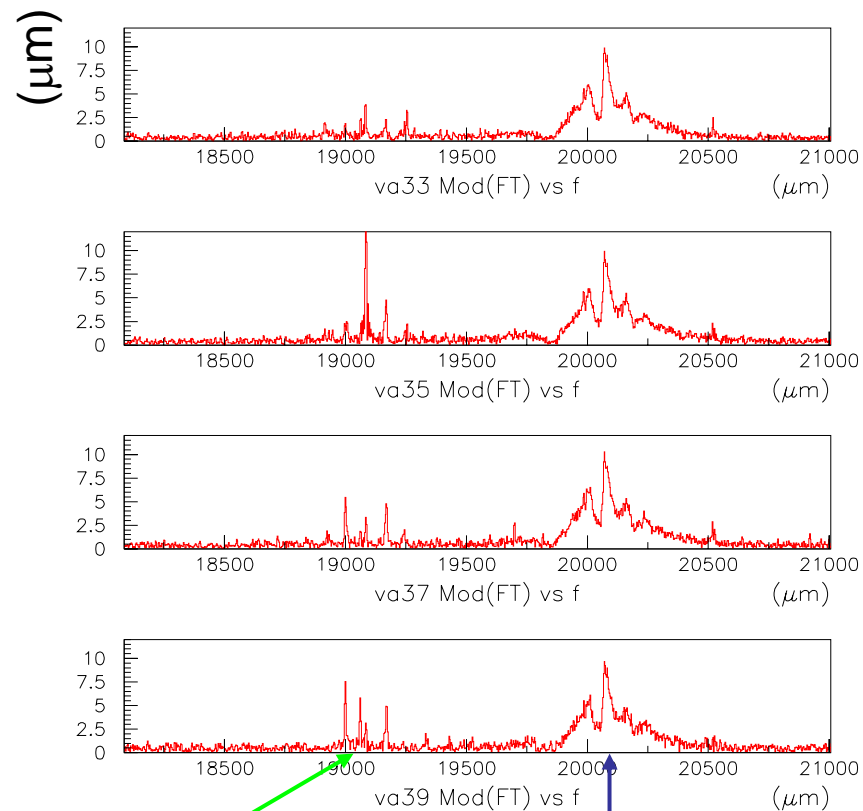


- Synchrotron line present in H but not V.
- 150 GeV expected sync frequency: 80 Hz.

Detail of Mod(FT) for H BPMs in A3, Feb 6/05, Coalesced



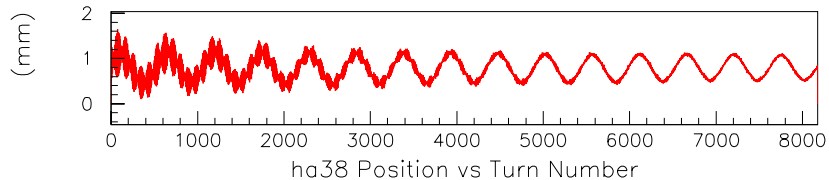
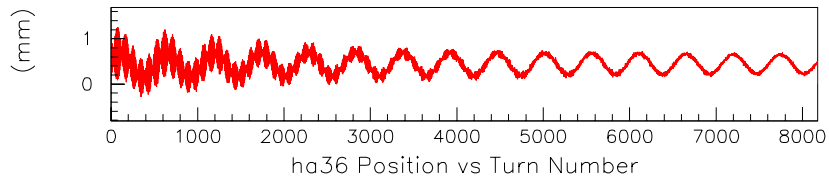
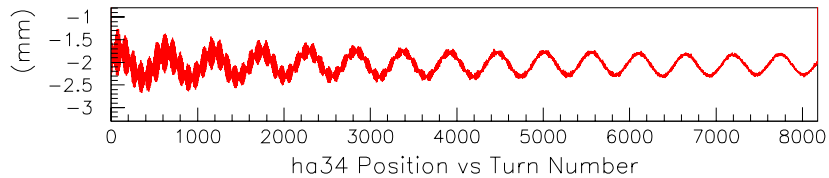
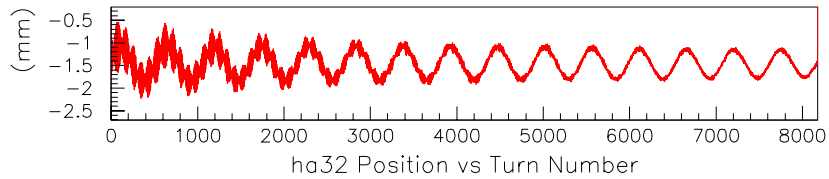
Detail of Mod(FT) for V BPMs in A3, Feb 6/05, Coalesced



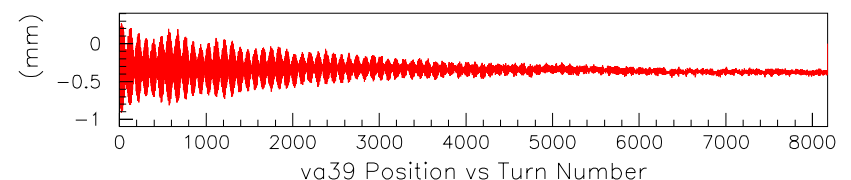
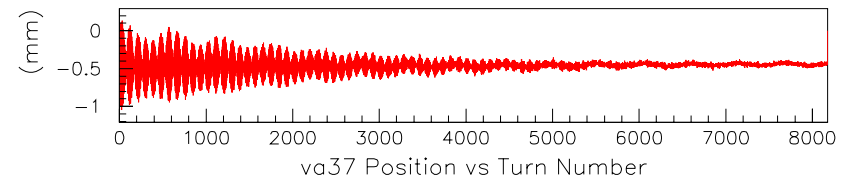
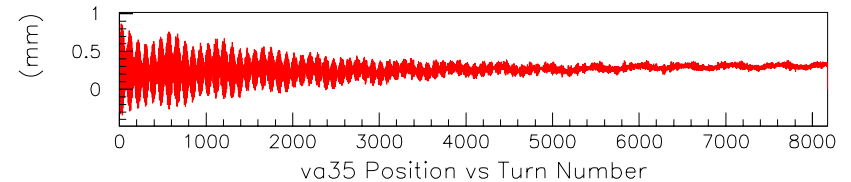
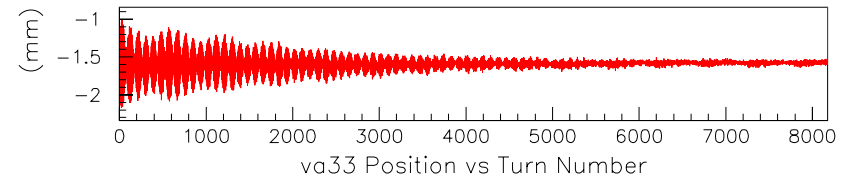
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Betatron Lines

Position for H BPMs in A3, Feb 7/05, Uncoalesced

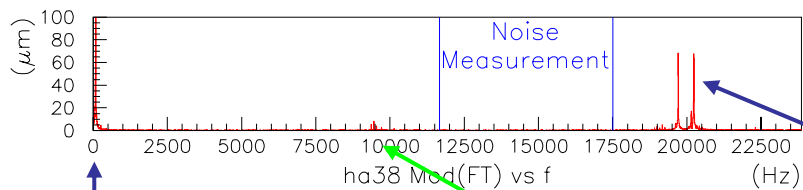
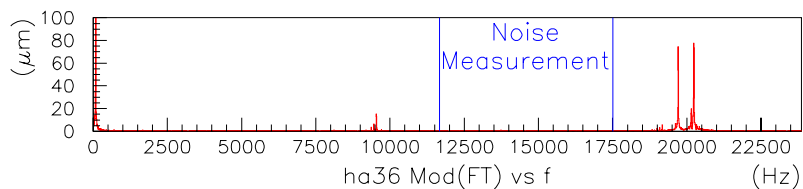
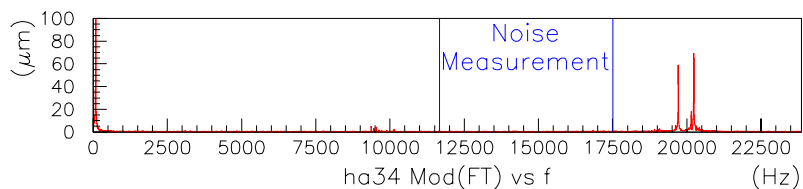
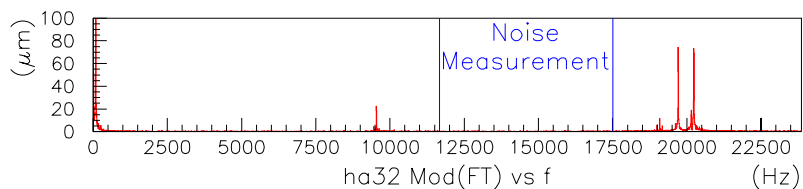


Position for V BPMs in A3, Feb 7/05, Uncoalesced

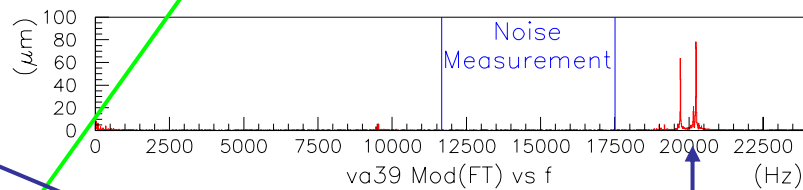
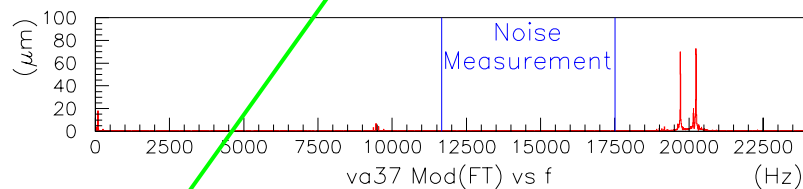
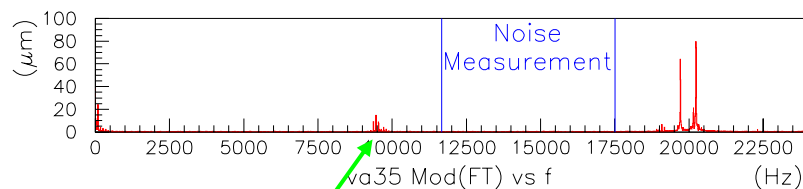
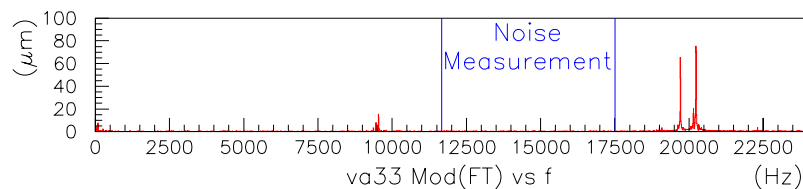


- Injection TBT; 150 GeV; 8192 turns.
- Uncoalesced beam. Tuneup shot with large injection mismatches.

Detail of Mod(FT) for H BPMs in A3, Feb 7/05, Uncoalesced



Detail of Mod(FT) for V BPMs in A3, Feb 7/05, Uncoalesced



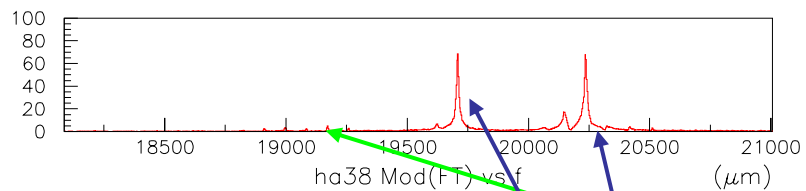
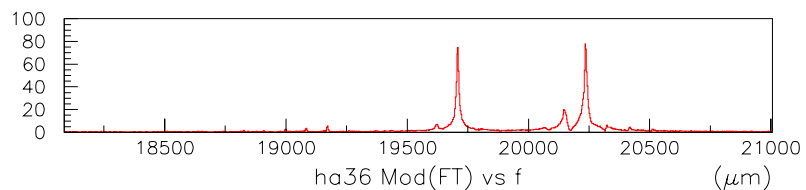
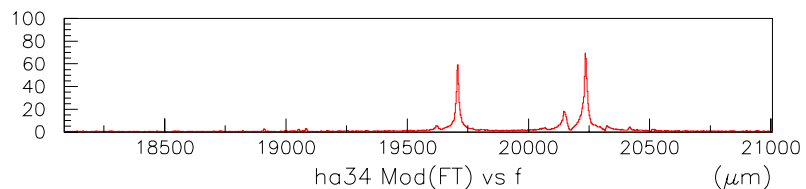
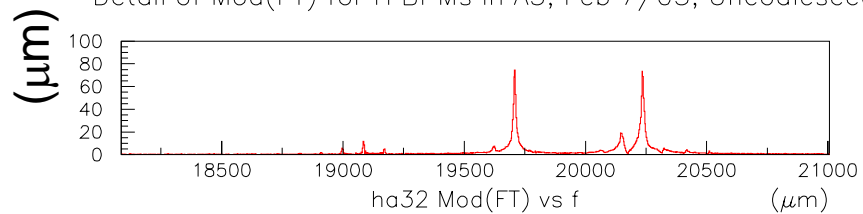
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Synchrotron Line

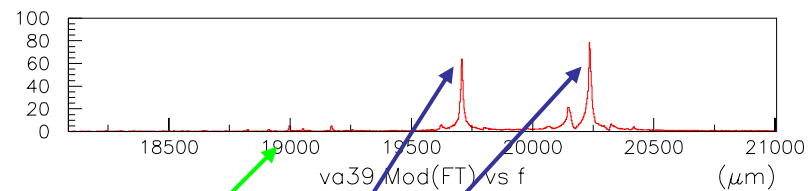
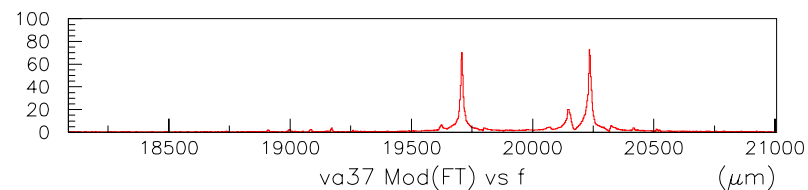
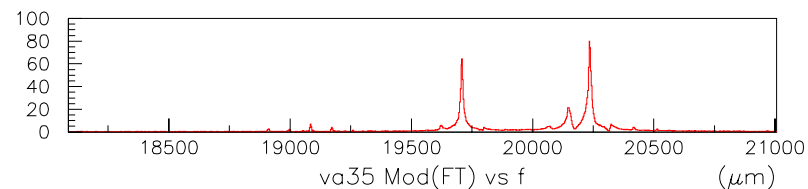
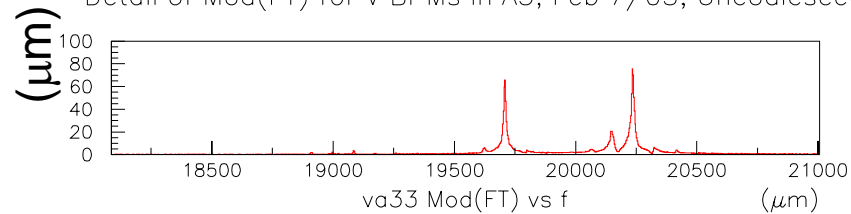
Bin Size: ~3 Hz

Betatron Lines

Detail of Mod(FT) for H BPMs in A3, Feb 7/05, Uncoalesced



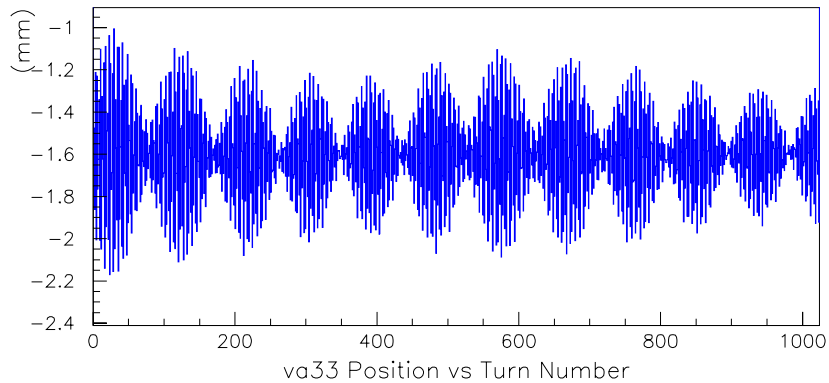
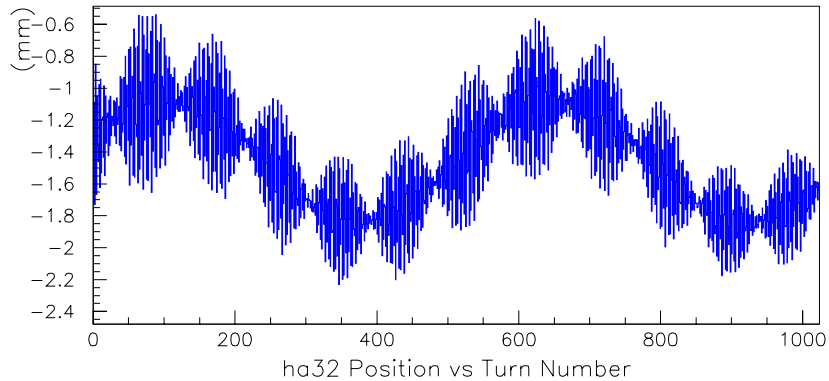
Detail of Mod(FT) for V BPMs in A3, Feb 7/05, Uncoalesced



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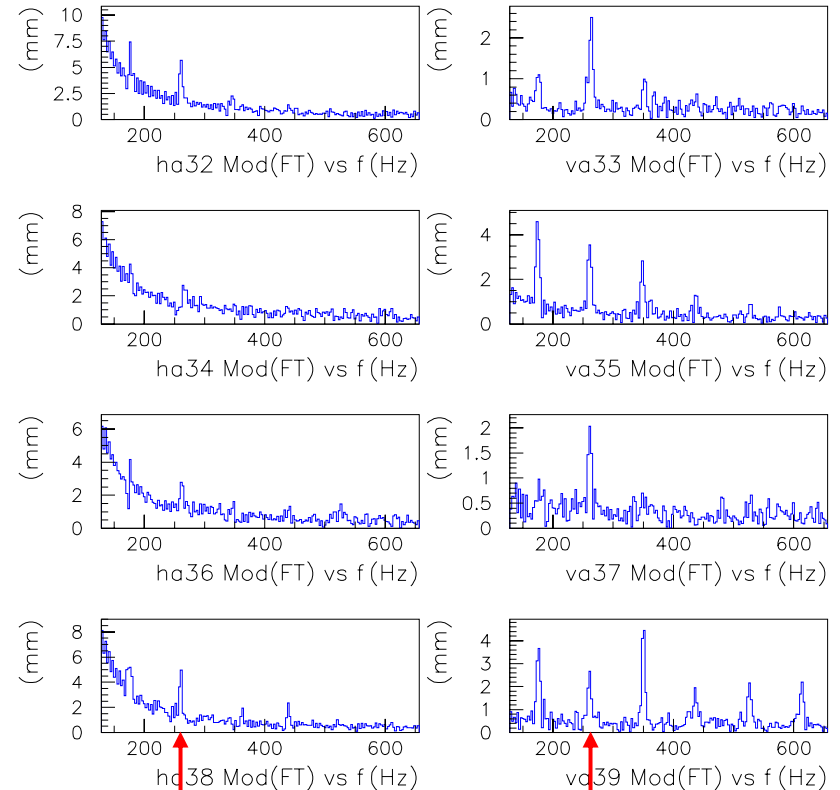
Betatron Lines

Position for HA32 and VA33, Feb 7/05, Uncoalesced



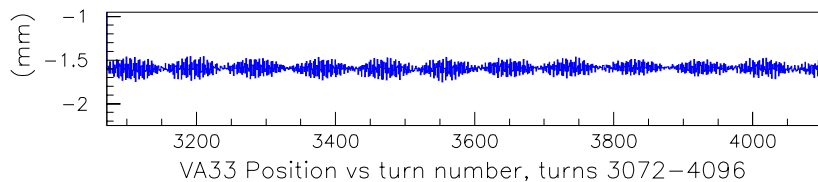
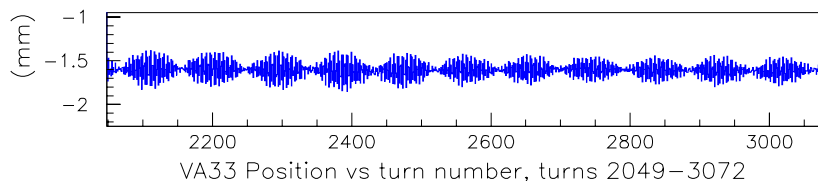
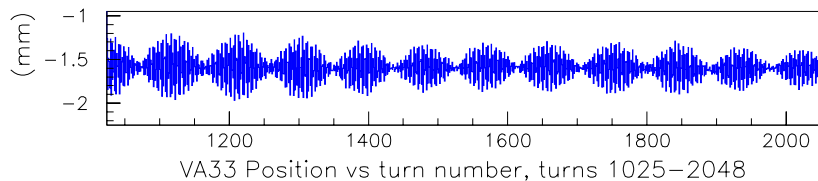
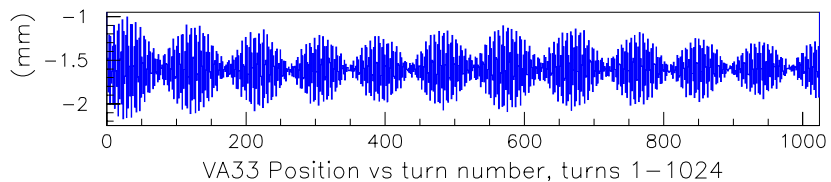
- HV coupling is clear.
- Frequency of envelope is about 260 Hz.

Fourier Transforms of Position Data, Feb 7/05, Uncoalesced

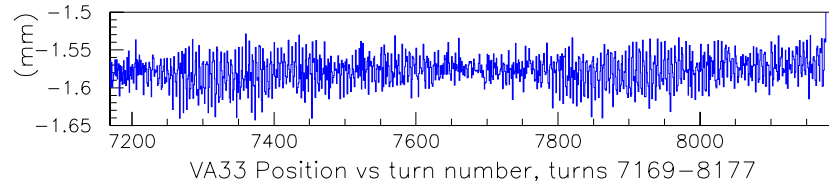
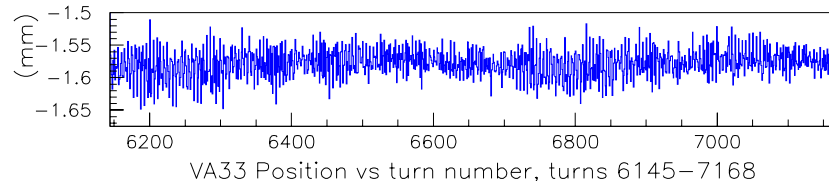
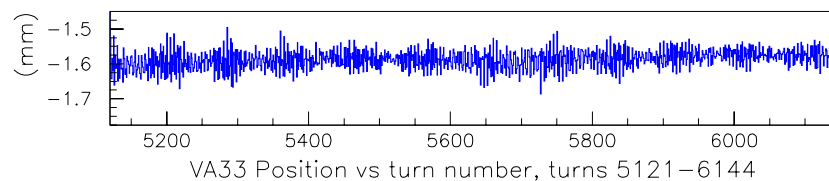
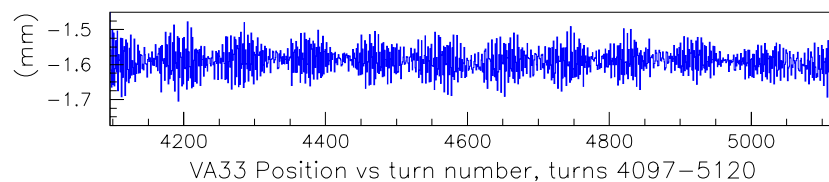


HV Coupling Frequency

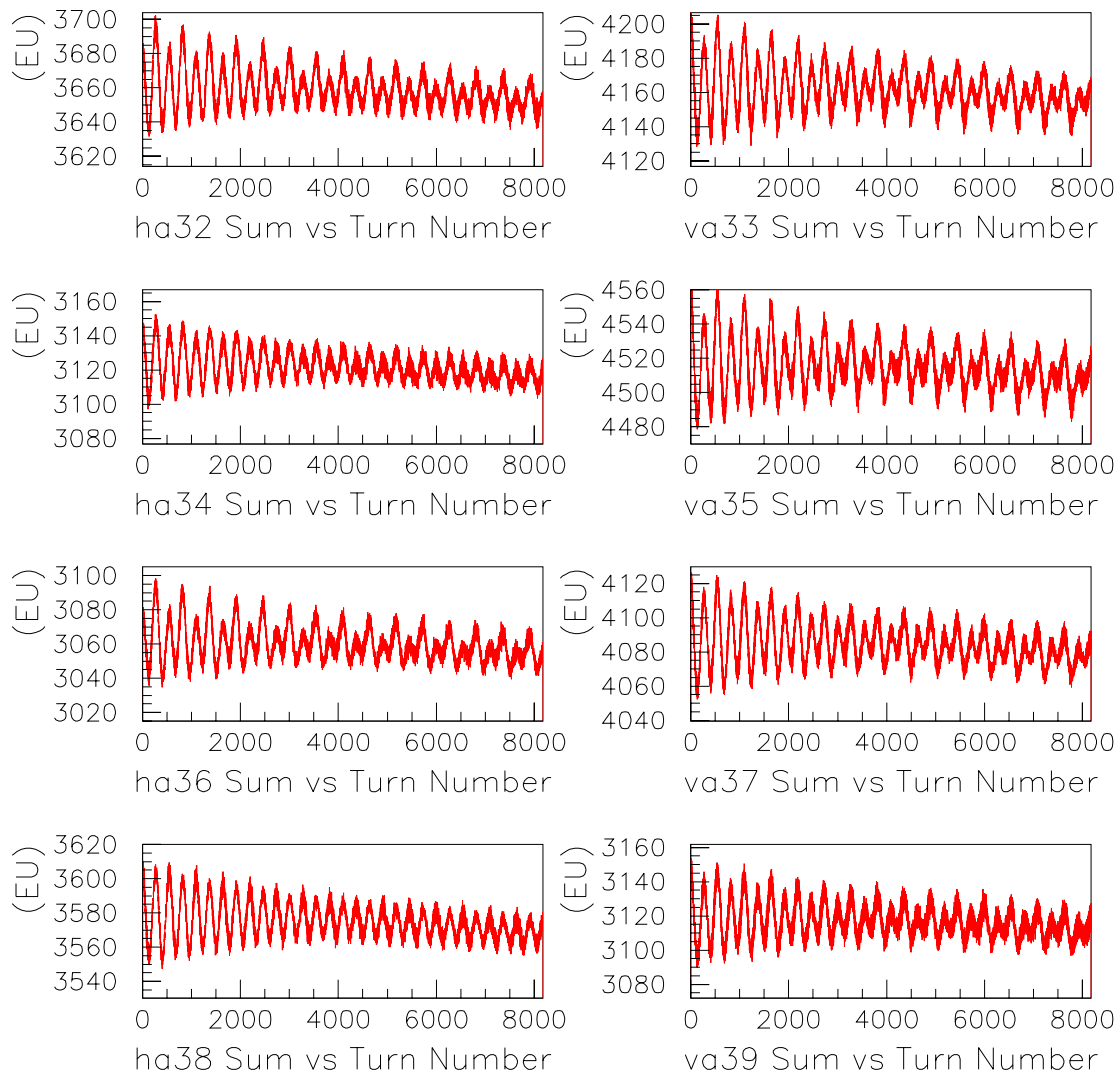
Position for VA33, Feb 7/05, Uncoalesced



Position for VA33, Feb 7/05, Uncoalesced

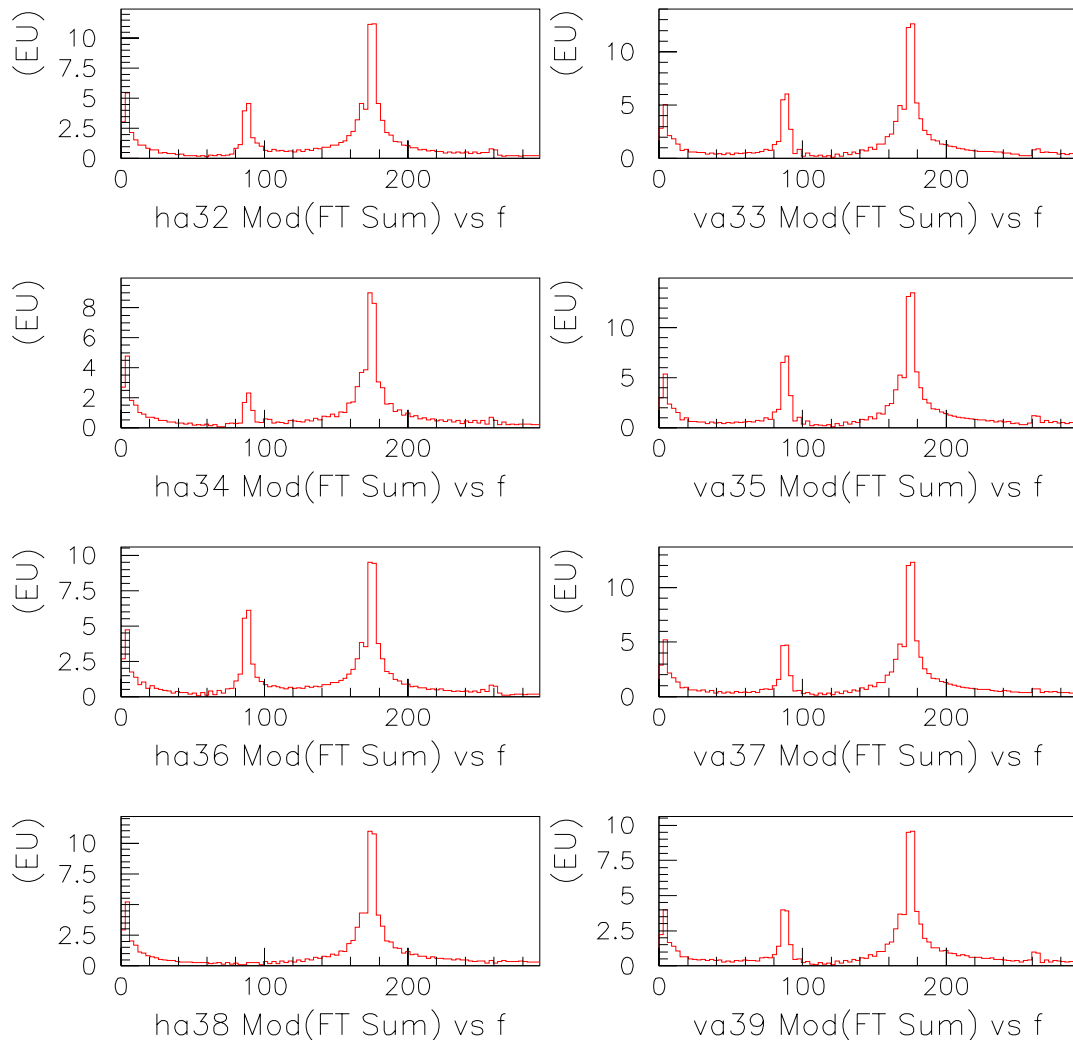


Sum Signals for BPMs in A3, Feb 7/05, Uncoalesced



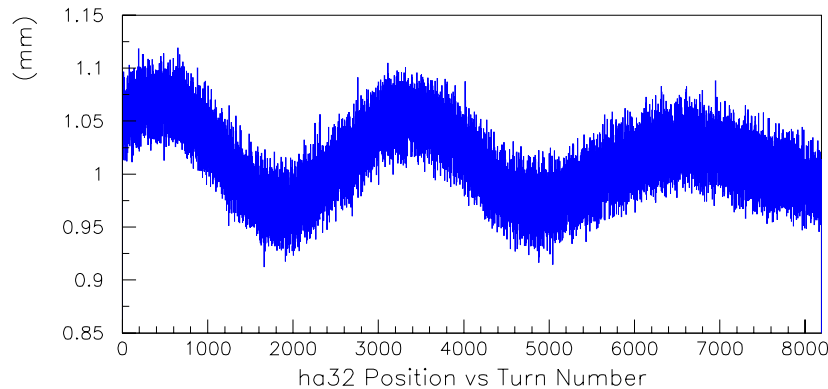
- Injection TBT.
- Sum signal (A+B)
- Same data as for positions.
 - Uncoalesced.
 - 150 GeV.
- Dominant frequency is different than in position data!

Detail of FT of Sum Signals for BPMs in A3, Feb 7/05, Uncoalesced

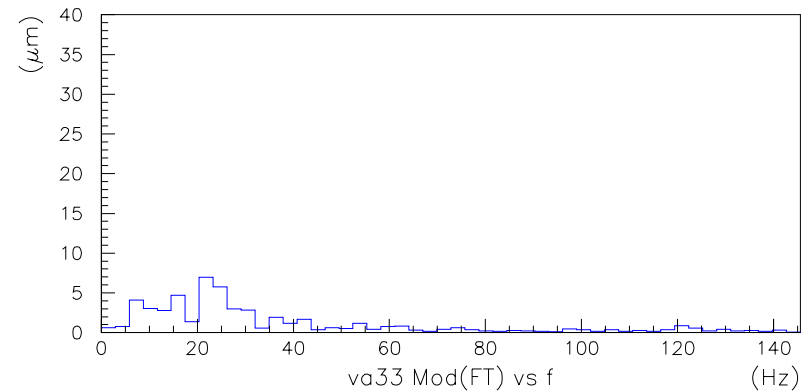
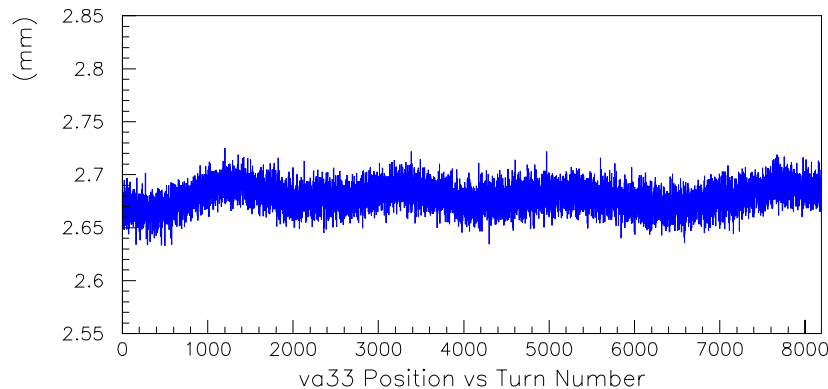
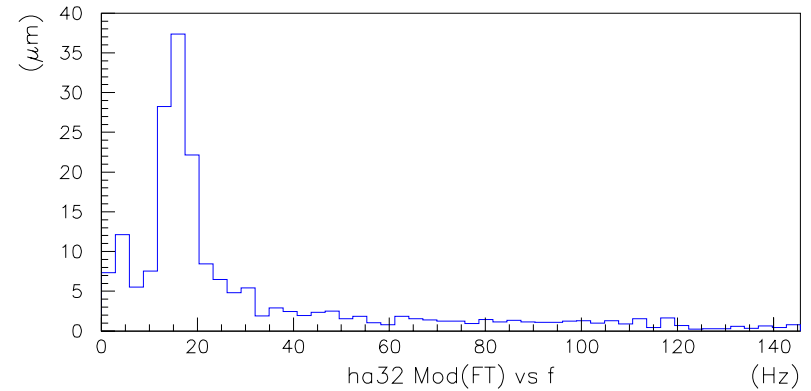


- Detail of Fourier transform.
- 150 GeV
 - $f_{\text{sync}} \sim 80$ Hz.
- Main structure at ~ 160 Hz is quadrupole oscillation of bunches in their buckets.

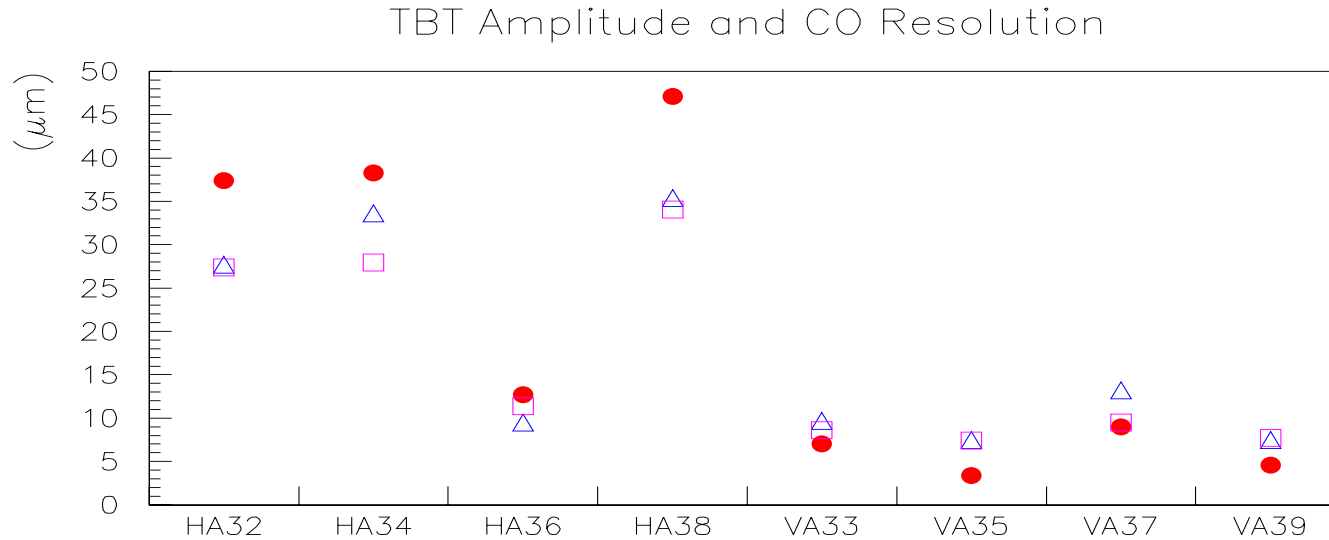
A3 TBT data from Middle of HEP Store



A3 TBT data from Middle of HEP Store



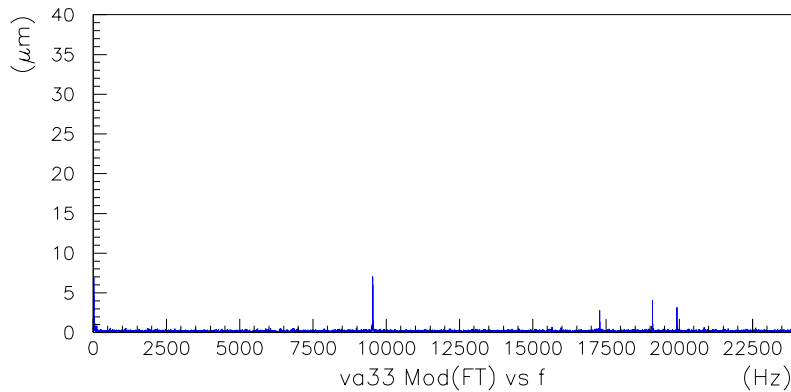
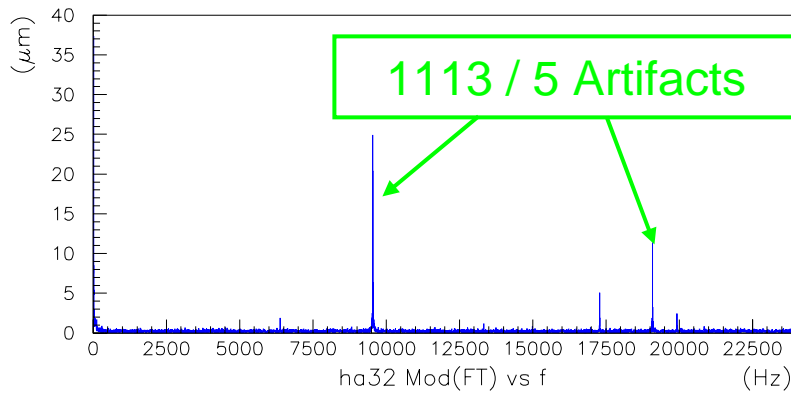
- TBT middle of HEP 36x36 store.
- 980 GeV; $f_{\text{sync}} \sim 37$ Hz.
- Similar features on other BPMs.
- Closed orbit resolution correlates with size of 15 Hz oscillations.



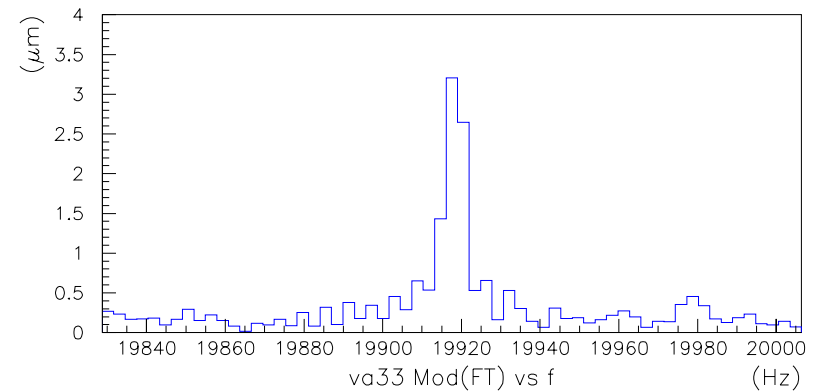
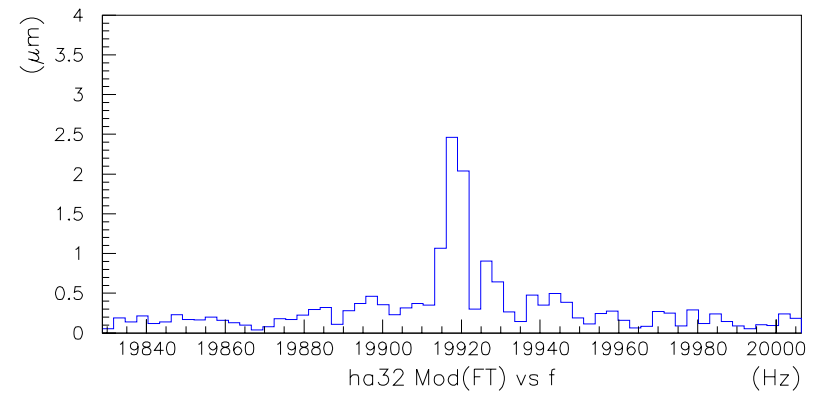
- Amplitude of TBT Motion
- △ RMS of Closed orbit Measurements
- Simple Model, $\text{sqrt}(0.5 \text{ TBT}^2 + 7^2)$

- Can observed TBT motion explain the variation in RMS of closed orbit measurements?
- In broad strokes yes. Still working on a quantitative model.

A3 TBT data from Middle of HEP Store



A3 TBT data from Middle of HEP Store



- Not sure why line at 19918 Hz is at the same frequency in both horizontal and vertical?

Conclusions

- TBT and Injection TBT are working.
- We can cleanly see:
 - Synchrotron lines
 - Betatron lines
 - Quadrupole oscillations
 - HV Coupling
 - 15 Hz noise.
- Can make quantitative measurements of these in 8192 turns.
- 1113/5 artifacts are present in safe places.

Further Details

- Documents earlier than 1565 discuss debugging the instrument.
- [Beams-doc-1565](#)
 - HEP Shot. One coalesced bunch.
 - Synchrotron, betatron motion.
- [Beams-doc-1566](#)
 - Tune up shot. Uncoalesced.
 - Synchrotron, betatron motion
 - Quadrupole oscillation of bunch in bucket.
 - Resolution.
- [Beams-doc-1571](#)
 - HV Coupling
- [Beams-doc-1577](#)
 - 15 Hz noise.
- Watch DocDb for latest developments.

Backup Slides

Fourier Transform

- $\tilde{F}(f)$, defined by:

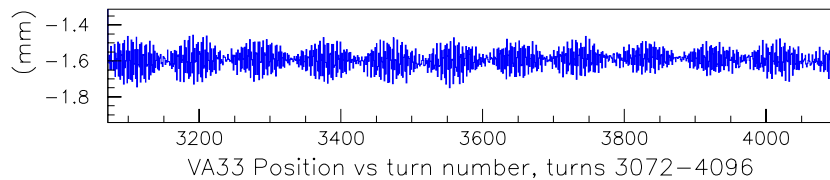
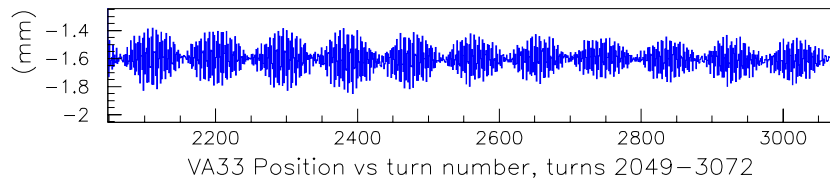
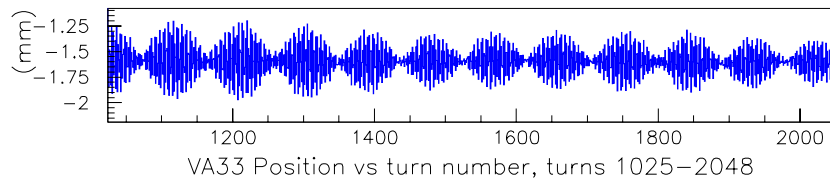
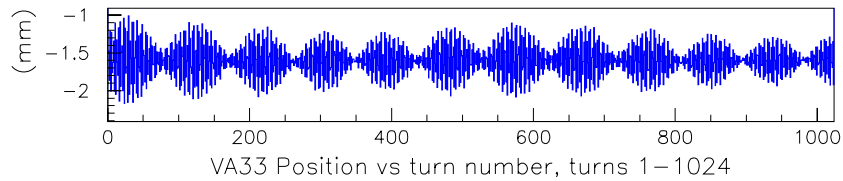
$$\tilde{F}(f) = C(f) \sum_{n=0}^{N-1} (P_n - \bar{P}) \exp(i2\pi f t_n)$$

- N is number of data points.
- P_n , t_n are position and time on turn n.
- $C(f)$ is a normalization factor.
- \bar{P} is mean position of all data.
 - Subtracted to remove alias at 0 Hz.

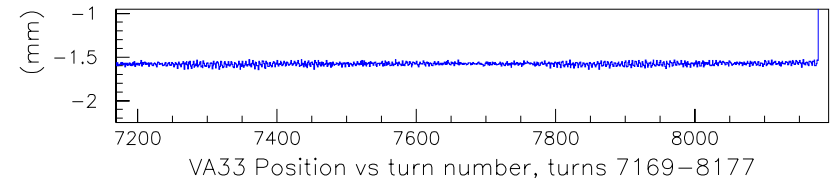
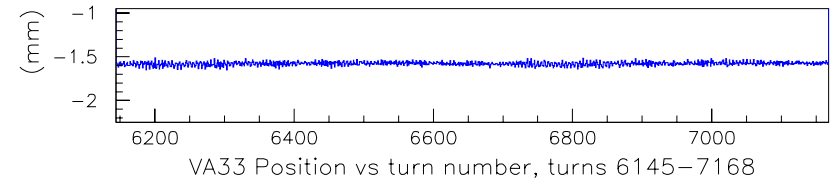
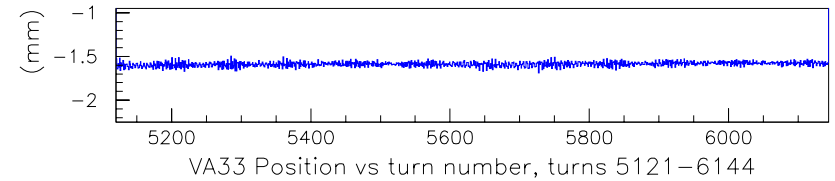
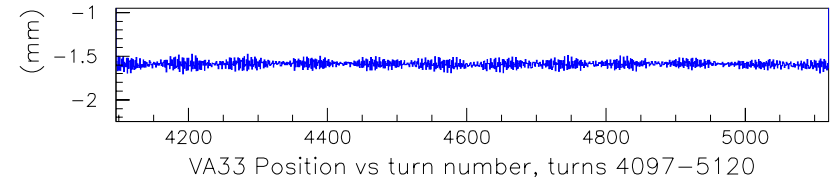
1113 / 5 Artifacts

- Digitizer is clocked at $7/5 f_{\text{RF}}$.
- After 7 cycles of this clock, and 5 cycles of RF, the $7/5$ RF clock is back in sync with the RF.
- After one full turn of 1113 RF cycles, the $7/5$ clock has not gone through a full cycle of 7 states.
- When first bunch of second turn arrives, the $7/5$ clock has a different phase than it did when the first bunch of the first turn arrived.
- After 5 turns, the two clocks are back in sync.
- [Beams-doc-1066](#)

Position for VA33, Feb 7/05, Uncoalesced



Position for VA33, Feb 7/05, Uncoalesced



- All 8 plots on same scale.